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Shape model and rotational state of dwarf planet Ceres from Dawn FC stereo images

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1. Introduction

In 2012, the Dawn mission completed its 14-month observation campaign at asteroid (4) Vesta and entered in March 2015 successfully into the orbit around its final target – the dwarf planet Ceres. Similar to the mapping strategy at Vesta, Ceres will be imaged in three different altitude orbits [1] Survey, High Altitude Mapping Orbit (HAMO), and Low Altitude Mapping Orbit (LAMO) using the onboard camera Dawn FC [2]. In June 2015 Dawn is going to start its Survey orbit and will acquire about 920 clear filter images with a resolution of about 400 m/pixel in eight different cycles. In each cycle Ceres will be mapped completely under similar illumination conditions (Sun elevation and azimuth), but different viewing conditions (by slewing the spacecraft off-nadir). This will allow us to analyze the images stereoscopically and to construct stereo topographic maps. The topography is particularly important because it is essential for derivation of physical properties of Ceres, precise ortho-image registration, mosaicking, and map generation of monochrome/color FC images and VIR images [3]. Furthermore we will determine a precise description of the rotational state of Ceres.

2. Methods

The stereo-photogrammetric processing for Ceres is based on a software suite that has been developed over the last decade. It has been applied successfully to several planetary image data sets [4-6]. The suite comprises photogrammetric block adjustment, multi-image matching, surface point triangulation, digital terrain model (DTM) generation, and base map production.

3. Processing and expected results

We will constrain all Survey clear filter images with our stereo requirements (Table 1) and will achieve at least triple stereo image coverage for the entire illuminated surface. Then we will apply multi-image matching for the set-up of a 3D control network. The control point network defines the input for the photogrammetric least squares adjustment where corrections for the nominal navigation data (pointing and position) will be derived. Furthermore we will refine Ceres's rotational state, formerly determined from Earth-based observations [7, 8]. Finally we will construct a global DTM (shape model) of Ceres with a lateral spacing of 16 pixels per degree (about 520 m/pixel) and a point accuracy of 70 m. As higher resolution data is obtained, the DTM will continue to improve.

4. First results from approach

In February 2015 during the Ceres Approach phase, 76 clear filter images were acquired to investigate the rotational characteristics of Ceres. During two observation sequences (RC1 and RC2) the entire illuminated surface of Ceres was mapped in visible wavelengths as a rotational movie with a nominal image scale of about 8 km/pixel and 4 km/pixel, respectively. We applied our stereo-photogrammetric processing described above and derived a 3D control point network. From that we determined the spin rate of Ceres to be 952.1532 degree/day, which perfectly matches the previous determination from ground-based data [7]. Additionally we refined Ceres's spin axis orientation to be: right ascension = 291.62° ± 0.2°, declination = 66.47° ± 0.1°, which matches within error the values formerly determined from Earth-based observations [8].

Parameters [°]	
Differences in illumination	0-10
Stereo angle	15-50
Incidence angle	0-60
Emission angle	0-60
Phase angle	5-160

Table 1. Requirements for stereo processing.

Finally we adjusted the nominal orientation and applied dense multi-image matching to compute a dense surface point cloud. From that we derived a first surface model of Ceres (see Figure 1) with a lateral spacing of about 4 km/pixel and mean point accuracy of 800 m. The reference coordinate system used to depict the shape model is defined by spin axis orientation (values above) and the prime meridian definition with W_0=170.90° [8]. This reference frame will be finally fixed using Survey orbit observations.

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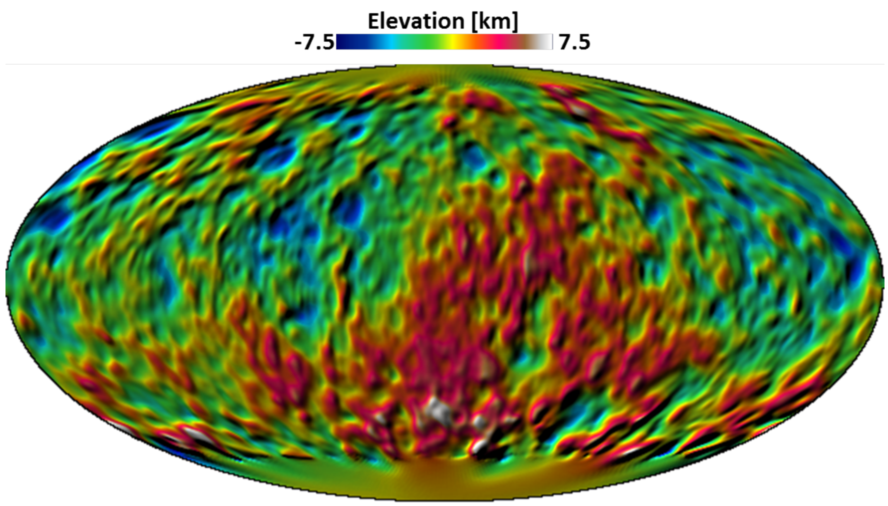

Figure 1. Global RC2 DTM of Ceres centered at 180° with a lateral spacing of about 4 km (hill-shaded color-coded heights) in Mollweide Projection (equal-area). Heights refer to a biaxial ellipsoid (482x482x445 km).